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West Sumatera Brown Rice Resistance to Fe

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***Abstract*— Brown rice is favored nutritious rice consumed by urban people whole the world as carbohydrate substitutes. This rice is appropriate for an urban community that concerns to a healthy lifestyle and diabetes people as the main staple food. One indicator of superior brown rice is resistant to abiotic stress, such as Fe. Fe is one of the main problems in cultivated land in Indonesia. The study aimed to study the West Sumatera brown rice resistance to Fe stress. West Sumatera belongs to the one province in Indonesia that can supply 2.5% of Indonesia rice requirement or 2 million tons in 2017. The research was conducted in the shade net house of Faculty of Agriculture, Andalas University, Padang, West Sumatera, Indonesia, from October 2017-January 2018. A completely randomized design was used in the assay and replied 3 times. 15 brown rice genotypes that consisted of 13 brown rice (Surian, Padi Ladang, Talang Babungo, Sungai Abu, Gunung Pasir, Perbatasan, Kekuningan, Pido Manggih, Siarang, Padi Telur, Sikarujuik, Jorong Mudiak and Teluk Embun) and 2 black rice genotypes (Sariak Alam Tigo and Solok) were used in the research. 2 genotypes (IR-42 and IR-64) were used as the control. The result showed that 5 West Sumatera brown rice genotypes were tolerant to Fe stress, Talang Babungo, Perbatasan, Kekuningan, Siarang, and Black Rice Solok. The result also showed that Fe affected the height of the plant, length of root, dry grain weight, and production of grain per pot. Black Rice Solok was the best genotype for grain production per hectare (3.3 ton).**

***Keywords*— black rice; brown rice; Fe; genotype; resistance.**

I. INTRODUCTION

Brown rice is favored rice consumed by the urban community. Brown rice is highly nutritious rice but has a lower calory compared to common rice [1]. 100 grams of brown rice contains 7.5 g protein, 0.9 g fat, 77.6 g carbohydrates, 16 mg calcium, 163 mg phosphorus, 0.3 g iron, 0.21 mg vitamin B1, and anthocyanin [2]. The presence of brown rice can be used as a white rice substitute with low calorie and its benefit for the human body, many people particularly urban community that consumed common rice as main carbohydrate source change their practice to consume brown rice[3]. The awareness of these people to a healthy lifestyle is the main factor in supporting this practice change.

This condition causes the demand for brown rice always increases year by year [4]. Indonesia is one of the countries that most of the people consume the rice as main staple food, the increasing of brown rice demand occurs, including West Sumatera, a region that is known as producer center of rice in Sumatera island and supplies the rice requirement of neighboring provinces such as Riau, Riau Island, Jambi, South Sumatera, Bengkulu and even exported to other islands in Indonesia such as Java, Borneo, Celebes and many other islands [5]. West Sumatera is also one province in Indonesia that can supply 2.5% of Indonesia rice requirement or 2 million tons in 2017 [6]. Almost All regencies, even municipalities in the province, make rice as the main crop cultivated by farmers such as Tanah Datar, Lima Puluh Kota, Padang Pariaman, Pasaman, Pasaman Barat, and Solok. This condition is supported by the location of the province that passed by equator line, a tropical zone that makes the province is appropriate for rice plant growth.

West Sumatera is one region in Indonesia that has a tropical rain forest climate. This condition makes the region rich in exotic genetic diversity resources. One of the germplasm from West Sumatera is brown rice [7]. 10 local brown rice and black rice genotype were found in this region. Other researchers reported 9 brown rice genotypes were found in Solok district, West Sumatera [8]. Those reports indicate that West Sumatera has many potential brown and black rice genotypes to be developed as superior variety. One important indicator of superior rice variety is resistance to Fe stress [9].

Fe or iron is the fourth most abundant element on earth, and soil contains 1%-5% of the toral iron of this planet. In cultivated soil, an average of Fe total concentration is 20-40 g/kg [10]. In Fe^{+2} state, Fe is mainly present in primary minerals and some phyllosilicates. Its oxidation to form Fe^{+3} leads to important changes in pedogenetic processes, resulting in the formation of a series of conjugate bases where Fe is coordinated with hydroxyls and water [11]. Most irons in the soil were found in iron oxides and hydroxides or silicate minerals [12]. These forms are not available for plant use.

For cultivated crops, Fe deficiency is a serious problem, particularly in calcareous soils [13]. Since Fe geochemistry is strictly connected to physical, chemical, and biological processes that occur in soil, factors influence these processes significantly affect the relative presence of the different Fe forms and, in turn, the macronutrients are available for plants [10].

Rice is a crop plant that also required enough amount of Fe for its metabolism. Fe, an essential micronutrient for cell functioning, plays a cofactor role in metabolic pathways, particularly in the photosynthesis process. However, an excessive amount of Fe is also not good for the growth and development of rice plants because it acts as a potent generator of reactive oxygen species (ROS), especially the hydroxyl radical, by Fenton reaction [14]. This radical is extremely toxic to cell metabolism, leads to oxidation of biological macromolecules such as proteins, lipids, and nucleic acids. This condition causes membrane leakage and even cell death [15][16].

Therefore, the goal of the plant breeding program is developing plant varieties resistance to abiotic stress such as Fe stress. The current explorations and studies of resistant brown rice to Fe stress barely give us a clear insight into the rice resistant to Fe (iron). Iron is one of the limited abiotic factors that can suppress the growing plant and decrease the yield of rice. Enhancement Fe concentration from 143 ppm up to 325 ppm in nutrient solution increases the iron toxicity symptom in rice plants [17]. Others report reported that the stress on a plant caused by Fe suppressed the growth and plant yield up to 12-100% [18]. This reality will always inhibit rice development in the land that contains high Fe.

The increasing of brown rice demand and cultivated soil problem causes the researcher should obtain a way to reach the goal. For solving the problem, the selection of local varieties is needed to obtain the varieties that tolerate to Fe stress. Varied geographical condition of West Sumatera enables to have varied brown rice germplasm. The study aimed to analyze the tolerant West Sumatera brown rice genotypes to Fe stress.

II. Material and Method

The research was conducted in the screen house of Faculty of Agriculture, Andalas University, Padang, West Sumatera, Indonesia. The research was conducted from October 2015 to January 2016. A completely randomized design was used in this experiment. 13 brown rice, 2 black rice, and 2 control genotypes were analyzed in this study. 13 brown rice genotypes were Surian, Padi Ladang, Talang Babungo, Sungai Abu, Gunung Pasir, Perbatasan, Kekuningan, Pido Manggih, Siarang, Padi Telur, Sikarujuik, Jorong Mudiak, and Teluk Embun. 2 black rice genotypes were Sariak Alam Tigo and Solok. The control genotypes were IR-42 and IR-64. All rice plants were grown in a screen house. Rice seeds were germinated on a seedbed (30 x 40 x 5 cm). 14 DAP plants were transferred to pots (diameter 15 cm; height 18 cm), one plant was planted in each pot. Urea fertilizer (0,35 g/pot) was applied 3 times, 0 DAP, 28 DAP, and 49 DAP. TSP and KCl fertilizer (0,18 g/pot respectively) were applied in planting time.

The appearance of Fe symptom on the plant could be observed in maximum tillering (± 56 DAP). The observation was grouped based on the Fe symptom score released by Indonesia Germplasm Commission [19]. Score 1. The growth and tillering normal; 2. The growth and tillering nearly normal, on old leaves tip, there are orange spots; 3. The growth and tillering nearly normal, the old leaves are purple or reddish-brown. 5. The growth and tillering are inhibited the leaves' color changes. 7. The growth and tillering stop, the color of leaves changes and die. 9. Mostly plants die (Figure 1). Data were analyzed using Duncan's New Multiple Range Test (DNMRT) at a significant level of 5%.

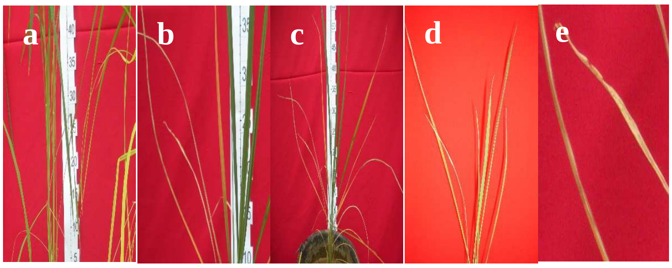

Fig. 1. The appearance of Fe symptom in rice plant. (a) Score 1, (b) score 2, (c) score 3, (d) score 5, (d) score 7, (e) score 9

III. Result and Discussion

A. The appearance of toxicity symptom on plant

The appearance of Fe toxicity symptom was observed in maximum tillering (32 DAP). The observation was grouped based on Indonesia Germplasm Commission [10]. The result of the observation is shown in Table 1. The result showed that 5 genotypes were tolerant if planted in Fe stress condition (Figure 2). Visually, Talang Babungo genotype had better adaptation ability (tolerant) than other genotypes if planted in under Fe stress condition. The other genotypes that showed quite a tolerance were Perbatasan and Kekuningan. Sikarojuik and Teluk Embun Genotypes were susceptible genotypes to Fe. It was marked by the stunting growth, old leaves were reddish-brown, from the tip of leaves, and finally died, and even the plant died before the generative phase. It was caused by these genotypes root could not hold Fe^{+2} that reduced by Fe^{+3} from flooding land so that Fe^{+2} was absorbed by plant root, continue to rise to the upper part of the plant and poisoned plant that marked Fe toxicity symptom in upper plant [20]. A report reported that in lowland rice, higher Fe^{+2} concentration in the rhizosphere also had antagonistic effects on the uptake of many essential nutrients, and consequently, rice yields reduction. In addition to reducing condition, increasing Fe^{+2} concentration in submerged soils of lowland rice was associated with the iron content of parent material, oxidation-reduction potential, soil pH, ionic concentration, level of fertility, and also rice genotypes. Iron toxicity was observed in flooded soil with pH below 5.8 when aerobic and pH below 6.5 when anaerobic [21].

The stage of Fe toxicity on plant consisted of 2 phases. First, phase 7 days after flooding. In this phase, the root couldn't oxidize the Fe+2 excess yet to be Fe^{+3} during flooding. Second, between primordial and flowering phases caused by the un-effective mechanism of root for resisting Fe^{+2} due to the root permeability [21][22]. The toxicity symptom of Fe only occurred in a specific condition that was in a flooded condition.

TABLE I
SCORE OF FE TOXICITY OF WEST SUMATERA BROWN RICE GENOTYPES

No	Genotypes	Score (32 DAP)	Level of tolerant
1	BrRTelukEmbun	9	Very Susceptible
2	BrRSikarojuik	9	Very Susceptible
3	IR-42	9	Very Susceptible
4	IR-64	9	Very Susceptible
5	BrRSurian	7	Slightly Susceptible
6	BrRPadiLadang	7	Slightly Susceptible
7	BrR Sungai Abu	7	Slightly Susceptible
8	BrRPidoManggih	7	Slightly Susceptible
9	BrRPadiTelur	7	Slightly Susceptible
10	BlRSariakAlamTigo	5	Slightly tolerant
11	BrRGunungPasir	5	Slightly tolerant
12	BrRJorongMudiak	5	Slightly tolerant
13	BrRTalangBabungo	3	Tolerant
14	BlKSolok	3	Tolerant
15	BrRPerbatasan	3	Tolerant
16	BrRKekuningan	3	Tolerant
17	BrRSiarang	3	Tolerant

Note :BrR : Brown rice; BlkR : Black Rice, DAP : Days after planting

Reduction condition in flooded rice field caused Fe toxicity by the dissolution of all Fe form to be dissolved form Fe^{+2}. This process involved solvent microbes [17]. The critical limit of Fe toxicity was 300-500 ppm [18]. The other report reported that the critical limit of toxicity in rice plants was 500-2,000 ppm [23].

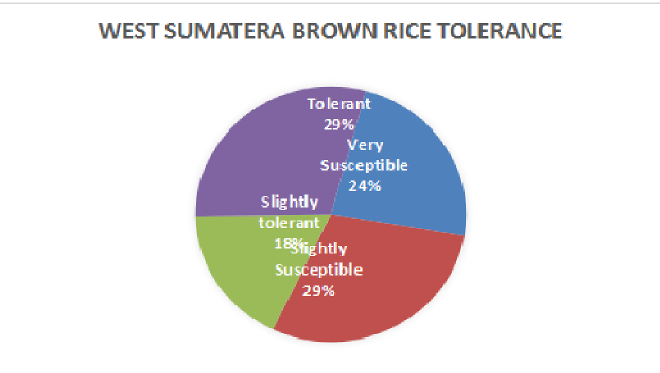

Fig 2. Percentage of West Sumatera brown rice tolerance under Fe stress according to the assay

Iron toxicity in rice was various. The common symptom of iron toxicity is visible on leaves. The spotting occurred in this part that started by young tissue. It was known as bronzing [24]. This condition was caused by an accumulation of oxidized-polyphenol [20]. Because of low Fe mobility in the plant, the specific symptom was started from reddish-brown spots of older leaves. The copper color spots furthermore spread to entire leaves, the next development of symptom was tip of leaves became orange, and finally dry from the top part. Appropriate management like aming acid soils, soil fertility improving, soil drainage at certain growth stage crop, use of manganese as an antagonistic element in uptaking of $Fe^{+2,}$ and planting Fe^{+2} resistant rice cultivars could reduce the problem of iron toxicity [21].

B. Fe content in root and canopy

The Fe content in root and canopy of brown rice was different, respectively (Table 2). The result showed that Sikarojuik and TelukEmbun genotypes contained a high level of Fe both in root tissue and canopy. It showed that these genotypes were un-tolerant genotypes to Fe. Fe in root tissue could not be held by Fe so that Fe^{+2} that formed was absorbed by the plant. It was marked by the plant that underwent quite severe Fe toxicity and just lasted until the vegetative stage and died [25].

Talang Babungo genotype had a quite high content of Fe in root tissue but lowest content in the canopy than other genotypes. This condition was caused by the Talang Babungo genotype that could hold Fe in the root so that Fe could not be absorbed by the plant [26]. The character of the tolerant plant to Fe is it could hold, resist and eliminate Fe in the root. Rice plant has a high tolerant level to Fe^{+2}in root zone if the root can oxidize Fe^{+2}into Fe^{+3}. This ability was influenced by nutrient availability in the plant. The other characteristic was releasing Fe to the soil surface, or the plant did not absorb half of Fe^{+2} [27]. This ability was influenced by respiration, and if the respiration is inhibited, the oxidation ability decreased and binded Fe in root tissue so that it could avoid Fe translocation to the upper part of the plant. This ability was influenced by soil salinity due to the high level of NaCl that could influence the root ability to distribute Fe^{+2} ion to the upper part of the plant [28].

TABLE II
FE CONTENT IN ROOT AND CANOPY OF WEST SUMATERA BROWN RICE GENOTYPES

No	Genotypes	Fe in root (ppm)	Fe in canopy (ppm)
1	BrRGunungPasir	448.08	356.08
2	BrRJorongMudiak	512.71	339.64
3	BrRKekuningan	549.09	339.27
4	BrRPadiLadang	418.02	362.08
5	BrRPadiTelur	524.83	341.89
6	BrRPerbatasan	530.14	340.83
7	BrRPidoManggih	518.52	375.58
8	BrRSiarang	523.83	344.14
9	BrRSikarojuik	629.64	453.27
10	BrR Sungai Abu	510.71	381.14
11	BrRSurian	480.63	341.64
12	BrRTalangBabungo	475.33	302.14
13	BrRTelukEmbun	655.89	459.33
14	BlRSariakAlamTigo	460.70	342.77
15	BlRSolok	474.64	343.39
16	IR-42	502.35	414.65
17	IR-64	500.73	407.89

Note :BrR : Brown rice; BlkR : Black Rice

The Fe^{+2} content in the canopy was much lower than Fe^{+2} content in the root of all genotypes. It showed that the root generally could hold Fe, and the amount of it that distributed to the upper part of the plant was slight. The ability of rice plants to hold Fe was depended on each genotype [29]. The root of tolerant genotype had more ability to hold Fe than un-tolerant genotype root [24]. The mechanism of rice tolerance to Fe toxicity depended on the oxidation ability of the root plant. Fe^{+2} ion in the root zone changed into Fe^{+3} so that it could be absorbed by the plant [28][30]. Several genotypes of rice plants had different tolerant levels to high levels of Fe. It was caused by the different structures of root that related to the oxygen movement from the upper part of the plant to the root part. Each genotype had a different ability to OH^- ion excretion [21]. The root of the genotype that released OH^- ion and increased the root layer surface absorbed slight Fe ion. This genotype was resistant to Fe [31].

C. Growth components

The response of brown rice genotypes was different for the height of the plant, respectively (Table 3). This condition was caused by the genetic characteristic of each genotype. Visually, several genotypes showed the height of the plant was not significantly different than other genotypes. It was not caused by Fe stress so that the growth was inhibited, but it was influenced by the genetic factor of the plant [32]. The sturdy stem and not many leaves showed the Fe toxicity symptom as an indicator of it. Fe stress also inhibits the development of tillering [33].

According to the result, Black rice Sariak Alam Tigo was the best genotype for plant height (76.40 cm). The plant height of rice was significantly affected by Fe concentration. Fe concentration above 200 ppm significantly reduced plant height. In 600 ppm of iron in variety IR-64 and Margasari, Fe caused the rice plant death. A higher concentration of Fe would inhibit the rice plant height [20].

For the length of root, Fe concentration also affected this part of the rice plant. The result showed that genotype Surian was the best genotype for the length of root (36.00 cm). The high concentration of Fe inhibited the root formation. In 50 ppm concentration of Fe, it started to affect the inhabitation of root elongation. The distribution of Fe in plant organs (root, stem, and leaves) was different [34]. The response of the root of brown rice genotypes was different. The ability of rice to Fe was affected by avoidance strategy and tissue tolerance. Avoidance in the plant was related to the oxidation ability of Fe^{+2} to be Fe^{+3} in the root surface so that the specific orange sediment was formed that was known as iron plaque [35]. The tolerant genotypes were more efficient in resisting Fe than susceptible genotypes. Low iron concentration occurred in the shoot was an avoidance mechanism that it was beneficial in plant resistance. The other report reported that genotype ITA 320 and Shwewar Tun was classified as tolerant-avoidance genotype due to these genotypes that could avoid the high concentration of Fe in leaves by holding Fe in root [36]. The occurrence of iron plaque in root showed that the presence of higher root oxidation ability in rice plants in avoiding Fe that was absorbed by the plant. The plant root oxidation ability played an important role in solving iron toxicity in rice plants. The presence of Fe oxidation in the root surface was a mechanism of the plant in solving iron toxicity [37][38].

Fe oxidation in root occurred due to the oxygen molecule was distributed from the atmosphere through the stem to root through aerenchyma gas canal. The aerenchyma formation depended on increasing ethylene production that stimulated by flooded presence. Aerenchyma was formed up to 20-50% of the total volume of rice root in a flooded condition. The aerenchyma formation was started from 2-4 weeks after planting, and the highest oxidation ability occurred in the maximum tiller formation stage [39].

TABLE III
GROWTH COMPONENTS OF WEST SUMATERA BROWN RICE GENOTYPES UNDER FE STRESS

No	Genotypes	Components			
		Height (cm)	Length of the root (cm)	Productive tiller	Total of tiller
1	BrRGunung Pasir	58.55 abcd	28.50 ab	3.50 a	4.50 a
2	BrR Jorong Mudiak	41.90 cd	20.00 ab	3.50 a	3.50 a
3	BrR Kekuningan	48.40 bcd	31.50 ab	3.50 a	4.50 a
4	BrR Padi Ladang	51.40 abcd	29.50 ab	3.00 a	4.00 a
5	BrR Padi Telur	44.40 bcd	20.50 ab	3.00 a	4.00 a
6	BrR Perbatasan	46.65 bcd	26.00 ab	4.00 a	4.50 a
7	BrR Pido Manggih	44.55 bcd	18.50 ab	0.00 b	4.50 a
8	BrR Siarang	56.55 abcd	24.00 ab	3.50 a	4.50 a
9	BrRSikarojuik	31.80 d	14.00 ab	3.00 a	4.00 a
10	BrR Sungai Abu	65.15 abc	25.50 ab	0.00 b	4.50 a
11	BrR Surian	70.65 ab	36.00 a	3.00 a	4.00 a
12	BrRTalang Babungo	64.05 abc	30.00 ab	4.00 a	4.50 a
13	BrR Teluk Embun	41.65 cd	11.00 b	0.00 b	3.00 a
14	BlR Sariak Alam Tigo	76.40 a	29.50 ab	4.00 a	5.50 a
15	BlR Solok	71.80 ab	27.50 ab	3.50 a	5.00 a
16	IR-42	30.21 d	11.34 b	3.00 a	3.00 a
17	IR-64	31.33 d	10.04 b	3.00 a	3.00 a

Note :BrR : Brown rice; BlkR : Black Rice

The Fe concentration did not affect the total of the tiller (Table 3). The formation of the tiller was affected by environmental and genetic factors. The plant that uses more assimilate produced the more tillers. Other report reported that the maximum tiller was also the by planting space. The planting space caused the water, and nutrients absorption was different. In the assay, the planting space was not used so that the similar result was obtained. The tiller was affected by Fe concentration. But, all genotypes almost showed a similar result (Table 3). The productive tiller was not related to a total of the tiller. This condition described that the total tiller did not always produce productive tiller. Productive tiller was mainly affected by genetic factors [20][32].

The main effect of Fe toxicity was the inhabitation of plant growth so that the mass of plants decreased. It was caused by the absorption of nutrient was inhibited. The development process of the plant was controlled by internal signals that depended on nutrient adequacy from the root so that the nutrients were the main limiting factor for growth and yield in most of the poor land to nutrient. The toxicity of Fe will inhibit growth by nutrients absorption, water, and cytokine of root because of the root penetration or hydraulic low. An efficient plant showed better growth than the nutrient deficiency conditions [34].

D. Yield components

Mostly the genotypes showed a different response to Fe stress. According to the result, Fe concentration affected the dry grain (Table 4). Genotype Talang Babungo was the best genotypes for dry grain (28.94 g). The grain weight was related to wet grain weight. Talang Babungo was also the best variety for wet grain weight (32.14). The different rice grain weight was affected by genetic factors [40]. Each variety had certain characteristics that produced the grain weight. The grain weight depended on palea and lemma size. It indicated the stability of a variety was determined by palea and lemma size. These sizes were regulated by a gene called OsMADS3428. In the *m34-z* mutant, a rice mutant, most of the grains from the secondary panicle branches were decreased in size, compared with grains from wild-type. But no differences were observed in the grains from the primary panicle branches. The amylose content and gel consistency, and a seed-setting rate from the spb were reduced in the m34-z mutant. Interestingly, transcriptional activity analysis showed that the OsMADS34 protein was a transcription repressor, and it influenced grain yield by suppressing the expressions of BG1, GW8, GW2, and GL7 in the m34-z mutant. This result revealed that OsMADS34 largely affects grain yield by affecting the size of grains from the secondary branches [41].

The water content of grain was affected by Fe concentration. The result showed that genotype Surian had the highest percentage of water content (30.94 %). Water content was the percentage of water in grain. Water content affected the quality of grain. More or less than 14.20% of grain water content decreased the quality of rice grain. It described this number was the ideal percent of water content. According to the result, there were no genotypes had a good quality of rice grain.

The plant tolerance to Fe toxicity was influenced by nutrients absorbed by the plant, climate, and growth stage [40]. The difference in grain weight was influenced by the size of a grain of each genotype. The plant growth affected the reproductive organ of a plant. The pithy seed is related to nutrient adequacy, especially P in leaves as an energy source in the cell metabolism process until being a pithy seed [42]. Besides that, absorbed nutrients after the generative stage were distributed to form seed. For the annual plant, in initiation seed, the seed will be a dominant use area where most of the assimilating results used for increasing the seed weight [32].

The yield of grain production per pot showed that Black Rice Solok Showed the highest yield than other genotypes (76.40 gram/pot)(Figure 3) or 3.3 ton/ha. This result is still much lower than the national production of Indonesia, 4,6 ton/ha [43]. The yield decreases up to 90% in a field that contains high Fe type red yellow Podzolic [44]. The yield decreasing of rice in iron filed up to 70% for susceptible genotypes and 30% for tolerant genotypes [45]. The result indicated that planting brown rice in Fe soil is not suggested due to the yield produced by brown rice genotypes was much lower than the average of national production.

The yield of rice was affected by grain weight. The grain was controlled by genetic factors. A gene is called NOG1. This gene controlled the number of panicles per plant that produced the grain. NOG1 encoded an enoyl-CoA hydratase or isomerase (ECH), a key enzyme in fatty acid β-oxidation pathway, and upregulation of NOG1 transcript levels significantly enhanced grain number and yield without negative effects in the number of panicles, grain weight, seed-setting rate, and heading date. The identification of NOG1 did not enhance our understanding of the molecular basis of regulation of grain yield but also provided a favorable gene for high-yield breeding rice. The introduction of NOG1 in Zhonghua 17 increased 25% of the yield [46] .

TABLE IV
YIELD COMPONENTS OF WEST SUMATERA BROWN RICE GENOTYPES UNDER FE STRESS

No	Genotypes	Components			
		Dry grain (g)	Grain wet weight (g)	Water content (%)	Grain production per pot (g)
1	BrR GunungPasir	23.68 abc	26.29 bc	21.22 d	58.55 abcd
2	BrR JorongMudiak	25.77 ab	29.32 ab	24.42 bcd	41.65 cd
3	BrR Kekuningan	27.60 ab	29.93 ab	20.71 d	48.40 bcd
4	BrR PadiLadang	18.94 c	21.50 c	24.18 bcd	51.40 abcd
5	BrR PadiTelur	23.81 abc	27.70 ab	26.12 bc	44.40 bcd
6	BrR Perbatasan	27.50 ab	28.89 ab	20.87 d	46.65 bcd
7	BrR PidoManggih	0.00 d	0.00 d	0.00 e	44.55 bcd
8	BrR Siarang	24.06 abc	28.27 ab	26.81 b	56.55 abcd
9	BrR Sikarojuik	0.00 d	0.00 d	0.00 e	41.90 cd
10	BrR Sungai Abu	0.00 d	0.00 d	0.00 e	65.15 abc
11	BrR Surian	22.11 bc	27.52 ab	30.94 a	70.65 ab
12	BrR Talang Babungo	28.94 a	32.14 a	22.57 cd	64.05 abc
13	BrR Teluk Embun	0.00 d	0.00 d	0.00 e	31.80 d
14	BlRSariak Alam Tigo	26.81 ab	29.46 ab	21.76 d	71.80 ab
15	BlR Solok	25.52 ab	28.47 ab	22.96 bcd	76.40 a
16	IR-42	20.45 bc	27.89 ab	21.73 d	32.03 d
17	IR-64	20.55 bc	28.52 ab	21.98 d	33.00 d

Note :BrR : Brown rice; BlkR : Black Rice

The other report reported that there was another gene that affected the grain of rice, called OsDCL3b. Know down of this gene decreased grain yield, but it increased the quality of rice grain [47]. The other gene that was reported to affect the yield of rice was ARE1. This genetic was known as a genetic suppressor of a rice *fd-gogat* mutant defective in nitrogen assimilation. ARE1 was a highly conserved gene, encoding a chloroplast-localized protein. Loss-of-function mutations in ARE1 caused the delayed senescence and resulted in 10–20% grain yield increases, hence enhanced nitrogen utilization efficiency (NUE) under nitrogen-limiting conditions. Analysis of a panel of 2155 rice varieties reveals that 18% indica and 48% aus accessions carried small insertions in the ARE1 promoter, which results in a reduction in ARE1 expression and an increase in grain yield under nitrogen-limiting conditions [48].

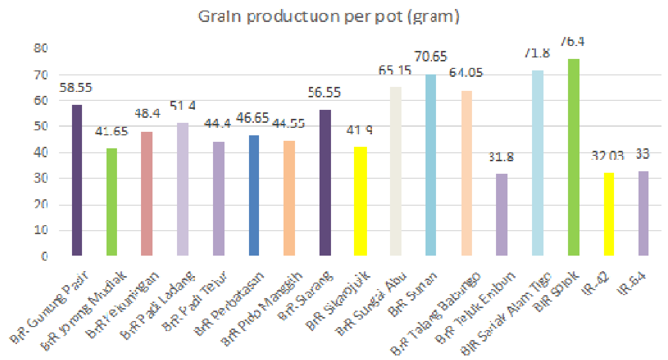

Fig. 3. Grain production per pot of West Sumatera brown rice genotypes under Fe stress

IV. Conclusions

5 West Sumatera brown rice genotypes were tolerant of Fe stress, Talang Babungo, Perbatasan, Kekuningan, Siarang, and Black Rice Solok. The result also showed that Fe affected the height of the plant, length of root, dry grain weight and production of grain per pot. Black Rice Solok was the best genotype for grain production per hectare (3.3 ton).

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